

Technical University of Denmark



## Wind turbine standard models

Status of IEC 61400-27

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## WIND TURBINE STANDARD MODELS

### STATUS OF IEC 61400-27

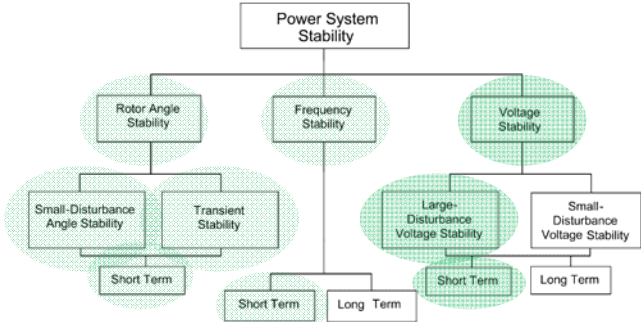
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 DEPARTMENT OF WIND ENERGY  
 CONVENER OF IEC 61400-27

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Wind Energy Systems Workshop, Roskilde, Denmark 2013-11-06

## Purpose of models



- IEC 61400-27 models are developed to represent wind power generation in studies of **large-disturbance short term voltage stability** phenomena, but they will also be **applicable** to study **other dynamic short term** phenomena:



**Classification of power system stability according to IEEE/CIGRE Joint Task Force on Stability Terms and Definitions. (© IEEE 2004)**

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## Potential users of the standard



- **TSOs and DSOs** are end users of the models, performing power system stability studies as part of the planning as well as the operation of the power systems,
- **Wind turbine manufacturers** will typically provide the wind turbine models to the owner,
- **Wind plant owners** are typically responsible to provide the wind power plant models to TSO and/or DSO prior to plant commissioning,
- **Developers of power system simulation software** will use the standard to implement standard wind power models as part of the software library, and
- **Education and research** communities, who can also benefit from the generic models, as the manufacturer specific models are typically confidential.

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## IEC 61400-27 – content



### Part 1 – wind turbines

- Definition of generic **terms and parameters** for wind turbine models
- Specification of **dynamic simulation models**:
  - Standard models for generic wind turbine topologies/ concepts / configurations on the market.
  - A method to create models for future wind turbine concepts.
- Specification of a **method for validation** of wind turbine simulation models

### Part 2 – wind power plants

- Definition of generic terms and parameters for wind power plant models
- Specification a method to create models for wind power plants including wind turbines, auxillary equipment and wind power plant controller.
- Specification of a method for validation of wind power plant simulation models

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## Key model specifications



- The models are for **fundamental frequency positive sequence** response.
- The models span the existing categories (**type 1-4**) of currently developed wind turbine generator technologies
- The models are **modular** in nature to allow for the potential of augmentation in case of future technologies being developed, or future supplemental controls features.
- The typical simulation time frame of interest is from **10 to 30 seconds**. Wind speed is assumed to be constant during such a time frame.
- The models are specified to work with simulation **time steps up to ¼ cycle**. As a consequence, the smallest time constants which can be included are ½ cycle, and therefore the bandwidth of the model cannot be greater than 15 Hz.
- The models **initialize to a steady state** from power flow solutions at full or partial power.
- Wind turbine dynamics such as turbine-generator inertia and first shaft torsional mode is only taken into account where it has significant **influence on the power at the wind turbine terminals**.

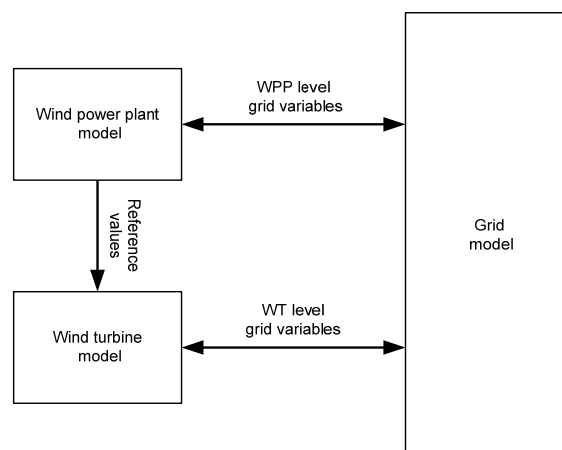
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## Interfaces between turbine, plant control and grid models

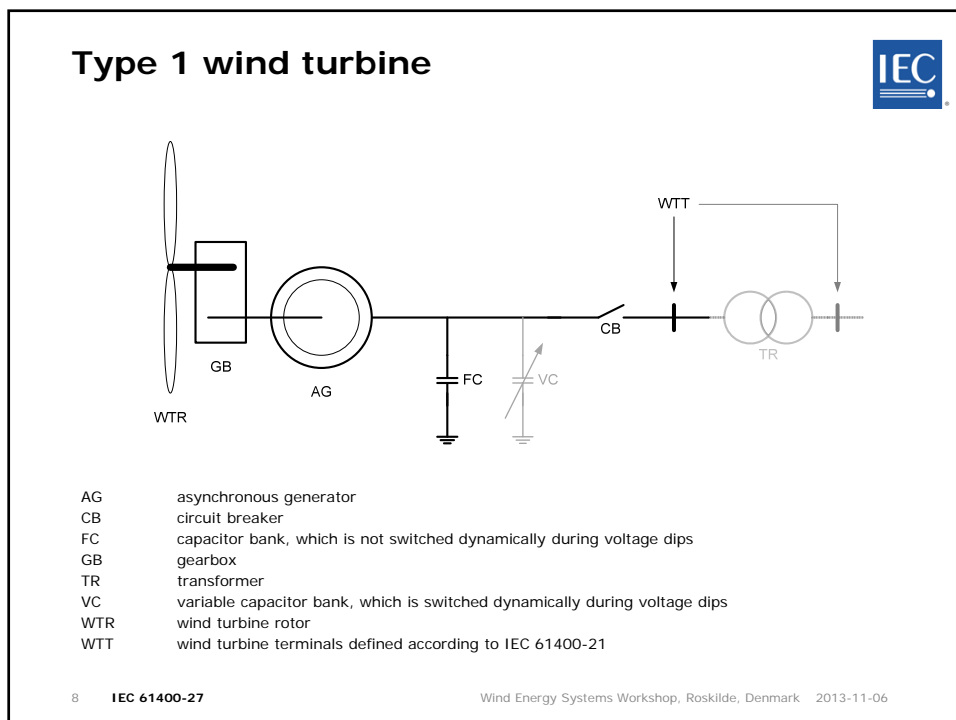
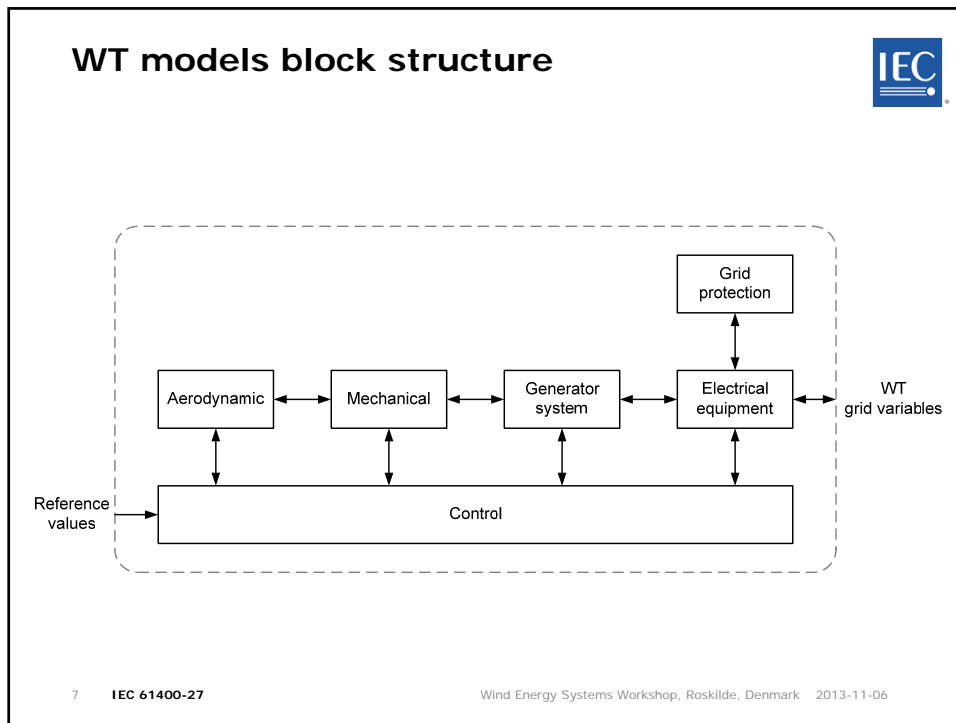


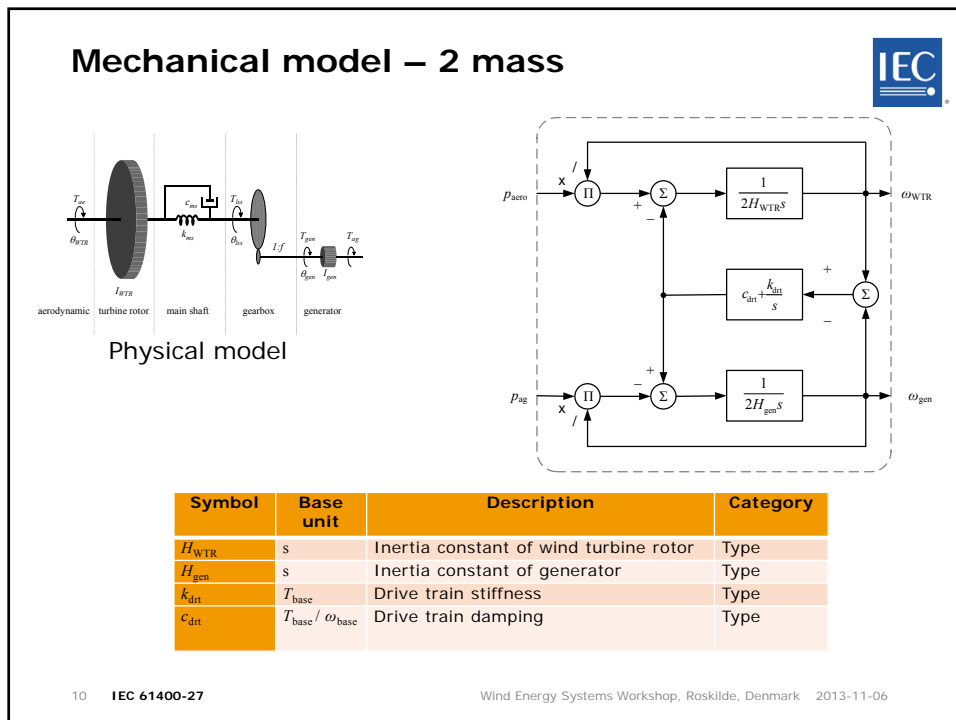
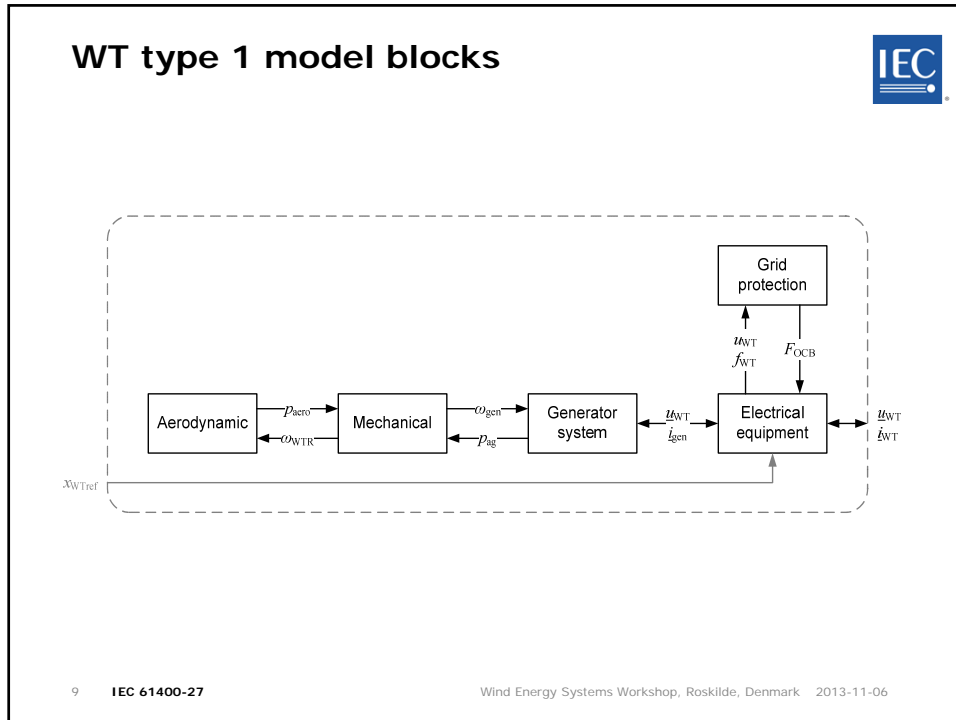
- Possible reference values:
  - Active power
  - Reactive power
  - Voltage
- Reference value symbols:
  - $p_{ref}$  (active power)
  - $x_{ref}$  (reactive power or voltage)



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## Parameter categories

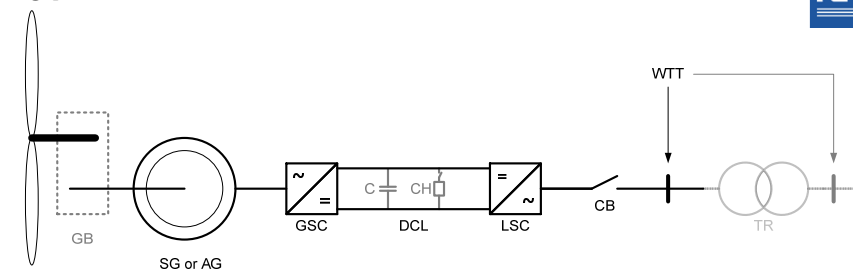


- The three parameter categories are defined as follows:
  - **Type dependent** parameters are characteristic to the specific wind turbine type. This is typically the case for mechanical and electrical parameters.
  - **Project dependent** parameters may be different for a specific wind turbine type, depending on the specific project. This is typically the case for control parameters set according to specific grid code requirements.
  - **Case dependent** parameters may vary depending on the specific steady state prior to the disturbance, e.g. depending on if the actual and / or possible power is nominal or partial. It is the responsibility of the wind turbine manufacturer to specify clearly how case dependent parameters depend on the specific simulation case.
- It is the intension to **reduce the number of case dependent** parameters to a minimum, but also be clear in stating the limited application range for a specific set of parameters.

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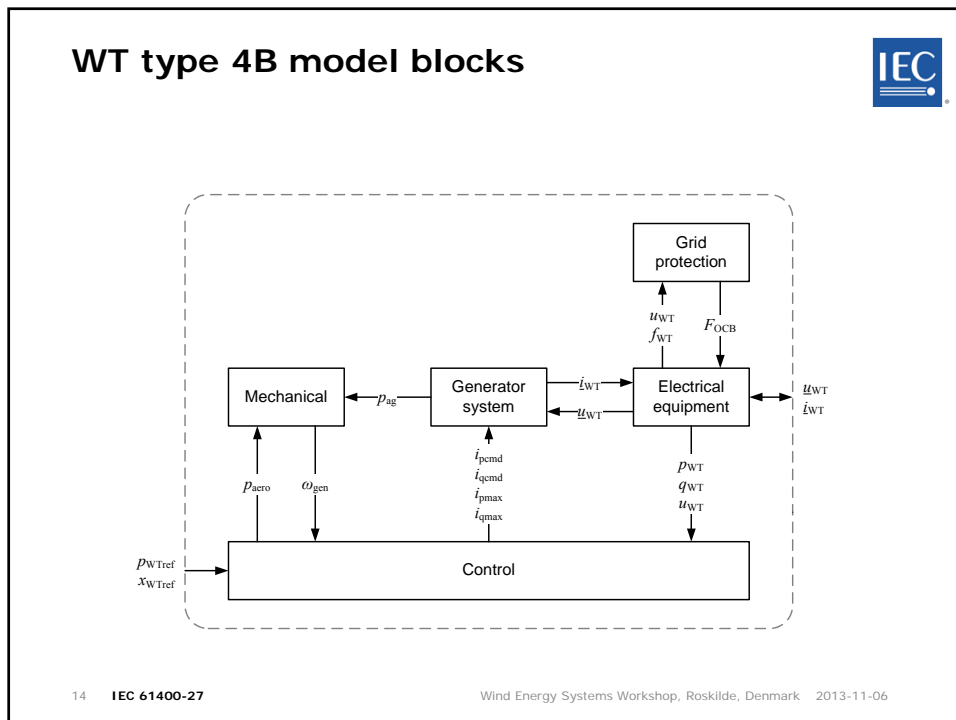
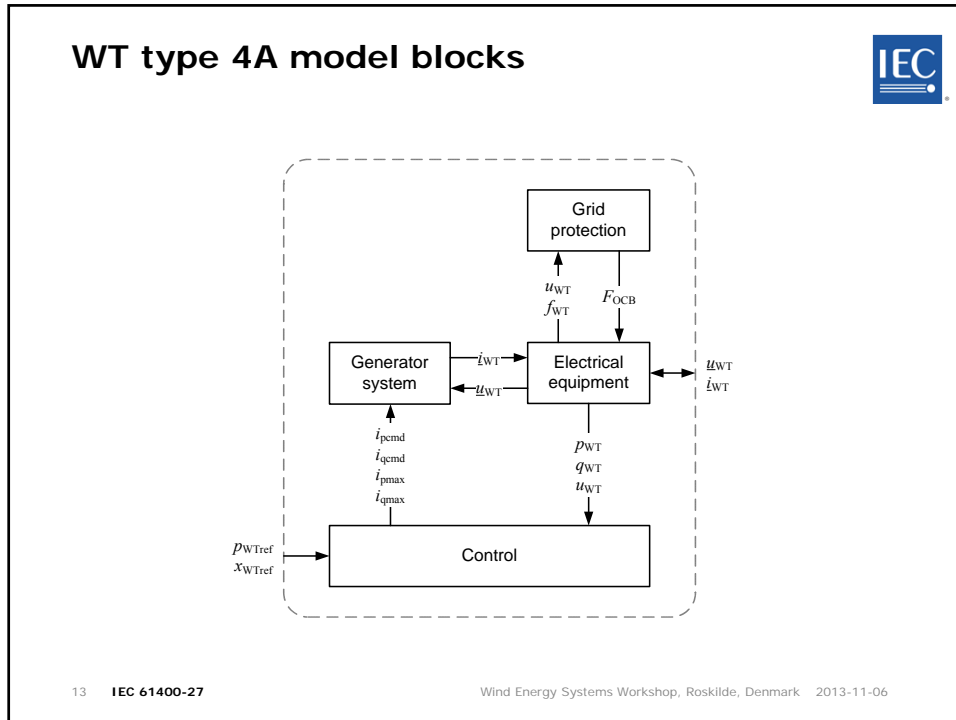
## Type 4 wind turbines



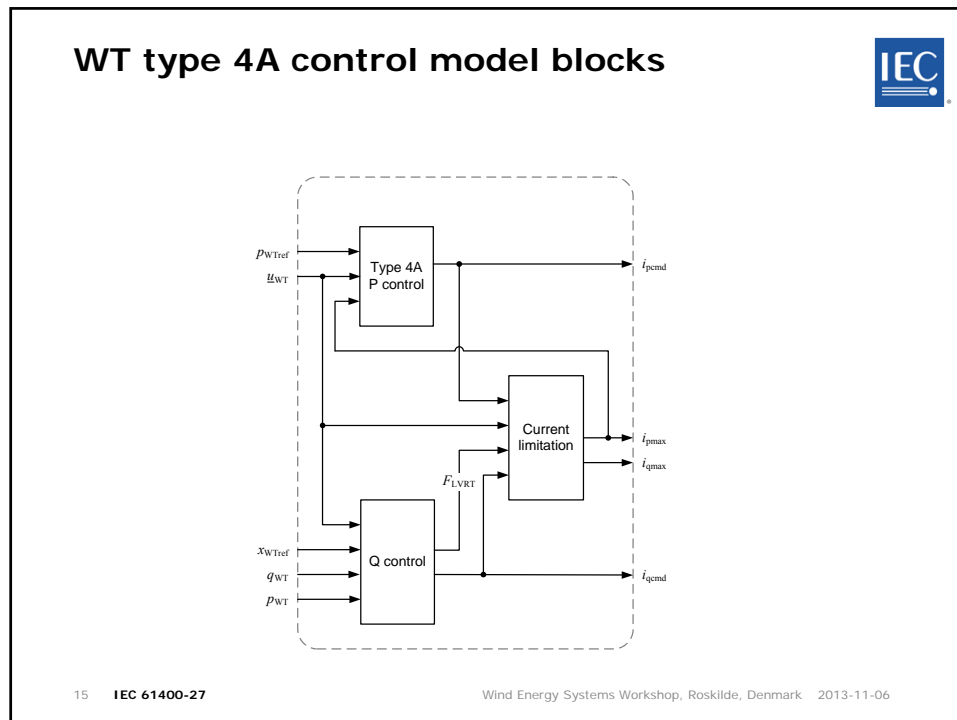
WTR	wind turbine rotor
WTT	wind turbine terminals defined according to IEC 61400-21
AG	asynchronous generator
C	DC link capacitor
CB	circuit breaker
CH	chopper
DCL	DC link
GB	gearbox
GSC	generator side converter
LSC	line (grid) side converter
SG	synchronous generator
TR	transformer

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### Q-control

- The Q control is shared between type 4 and type 3
- Q-control model support four different wind turbine normal operation modes:
  - Voltage control
  - Reactive power control
  - Open loop reactive power control (only applicable with closed loop at plant level)
  - Power factor control
- Q-control model support three different wind turbine LVRT operation modes:
  - **Voltage dependent** reactive current injection
  - Reactive current injection controlled as the pre-fault value plus an **additional voltage dependent** reactive current injection
  - Reactive current injection controlled as the pre-fault value plus an **additional voltage dependent** reactive current injection **during** fault, and as the pre-fault value plus an **additional constant** reactive current injection **post** fault

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## Validation procedure

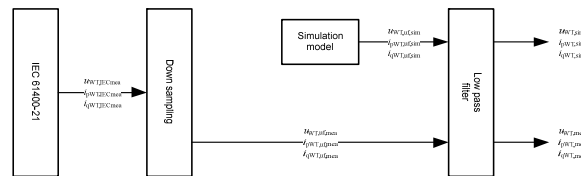


- The validation procedure is based on wind turbine tests according to IEC **61400-21**.
- The validation procedure includes the following wind turbine functional characteristics:
  - Validation of the simulation model response to **voltage dips**.
  - Validation of the simulation model response to **changes in reference values**.
  - Validation of the simulation model **grid protection** functionality.
- The model and test must **refer to** the same **wind turbine terminals** to ensure that measurements and simulations refer to the same point. According to IEC 61400-21, the wind turbine terminals are defined by the manufacturer and thus can be either:
  - the low voltage side of the generator step-up transformer, or
  - the high voltage side of the generator step-up transformer.
- To comply with the validation procedure, simulated **positive sequence values** shall be validated against the measured positive sequence values

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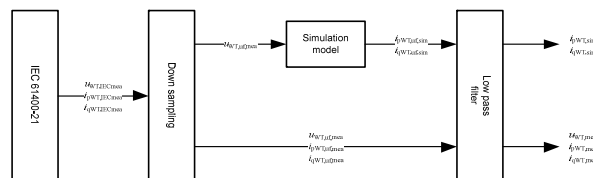
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## Validation - Signal processing



Full grid simulation

$$x_{\text{error}}(n) = x_{\text{mea}}(n) - x_{\text{sim}}(n)$$



Play-back

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## IEC 61400-27 – timeline



### Part 1: wind turbines

- 2008-12: NP
- 2009-04: 88/347/RVN
- 2012-01: 88/424/CD
- 2013-08: 88/463/CC
- 2013-11: 88/464/CDV
- 2014-08: FDIS
- 2014-11: Publication date

### Part 2: wind power plants

- 2012-04: 88/431/NP
- 2012-08: 88//RVN
- 2014-06: CD
- 2015-03: CC
- 2015-06: CDV
- 2016-03: FDIS
- 2016-06: Publication date

NP: New (work item) Proposal

RVN: Result of voting from National committees

CD: Committee Draft

CC: Compilation of Comments from National committees

CDV: Committee Draft for Voting

FDIS: Final Draft International Standard

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## Application Note



- The **scope** of the Application Note is to provide a **Benchmark** to support the implementation of dynamic simulation models for wind turbines being developed by the WG27 and fully documented in IEC 61400-27-1
- The dynamic model of all types of wind turbines will be **implemented in** the following power system simulation platforms:
  - DIgSILENT PowerFactory.
  - Eurostag
  - Dymola
  - Matlab Simulink
- **A set of generic data is used.** This data is not proprietary from any wind turbine manufacturer.
- The **external network** layout is based on the **WECC** proposal of typical diagram of a typical wind power plant

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## Summary



- **Part 1 (wind turbines):**
  - Wind turbine models for type 1-4 are at CDV stage, **standard expected 2014**
  - Models:
    - Type 1, type 3 and type 4 models are validated by manufacturers
    - Type 2 model adapted from WECC
  - Validation procedure based on test standard IEC 61400-21
- **Part 2 (wind power plants):**
  - **Standard expected 2016**
  - Work on wind power plant models started, presently **plant control model available**
  - Validation procedure relies on new test standard IEC 61400-21-2 for plant level tests

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## Participating members of IEC TC88 WG27



- |  |  |
|--|--|
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[www.iec.ch](http://www.iec.ch) (Search TC88 WG27)

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